U. S. DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN No. 1635

SURFACE IRRIGATION IN THE EASTERN STATES

IN THE EASTERN PART of the United States irrigating to increase production and to protect valuable crops from drought has been done chiefly by two methods—spray irrigation and subirrigation. Both systems are expensive, and subirrigation is not satisfactory except under special soil conditions. Little attention has been given in the East to the irrigation of the less valuable crops or the watering of the more valuable crops by a cheaper method.

This bulletin explains surface irrigation, which is simpler and less expensive than either spray or subirrigation. The information should be helpful to eastern farmers whose crops have suffered from drought but who from their knowledge of the high cost of the spray method and of the limited applicability of subirrigation have been discouraged from attempting irrigation of any type.

This bulletin supersedes Farmers' Bulletin 899, Surface Irrigation for Eastern Farms.

Washington, D. C. Issued September, 1930

SURFACE IRRIGATION IN THE EASTERN STATES

By F. E. STAEBNER, *Associate Drainage Engineer, Division of Agricultural Engineering, Bureau of Public Roads*

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INTRODUCTION

IN NEARLY ALL parts of the Eastern States the yearly rainfall is more than enough to grow good crops if rains come at the right times, but nearly every year some crops suffer from lack of moisture. Although this is well known, the losses from drought are not regular enough nor sufficiently widespread to force general practice of irrigation to supplement rainfall.

It is not to be expected that irrigation would be worth while for all crops nor in all parts of the East. But in those sections where dry periods occur often, a farmer should be able to increase his average production with the aid of irrigation. However, to justify the cost, the crops raised must be worth more than those raised without irrigation. This increased value must, on the average, be at least large enough to cover taxes, interest on the original cost, and the depreciation, maintenance, and operation charges on the necessary equipment. This means more intensive farming, sure markets, and the ability to grow and handle a greater quantity or a higher grade of crop, or both.

In many cases the probable increase in crop value is not enough to pay for putting in a spray-irrigation plant. In such cases a cheaper method of applying water may be profitable, as for instance where high-priced crops such as green beans, eggplant, etc., are grown by field-crop methods, or where less valuable crops are grown such as Lima beans and potatoes, which respond well to irrigation. Under such circumstances it may be well to consider surface irrigation.

IRRIGATION METHODS

Three methods of irrigation are employed in the Eastern States. These are known as subirrigation, spray irrigation, and surface irrigation. The latter method, however, has been employed far less than its possibilities warrant.

Subirrigation consists in watering the soil and the plant roots from below rather than from the ground surface or above. The water is delivered to the soil either from open ditches or from the open joints of tile laid underground. From these ditches or tile lines the water seeps into the soil of the field to be watered. Subirrigation requires an open surface soil, and a tight subsoil that will hold the water within the root zone of the plants. For successful subirrigation the surface of the ground must be level or at least have a slight, uniform slope. More water is required than for the other methods; therefore it seldom pays to pump water for subirrigation. Where conditions are favorable it is a most excellent method, but unfortunately these conditions are to be found in but few places in the eastern part of the United States.

In spray or overhead irrigation,[1] water is applied to crops in a fine spray. The method can be used on either level or hilly land and on any type of soil. The water is supplied under pressure, which is provided by an individual pumping plant unless city mains are tapped. The distribution system of the most common type of spray plant costs from $175 to $225 an acre irrigated. The main pipe line running from the water source to the field, and the pumping plant or connection to a supply main, involve additional expense. The type of system just referred to, for 5 and 10 acre units where pumping is from wells or streams to adjacent lands, costs for construction from $250 to $375 an acre, and sometimes more. Thus the crop which will justify irrigation by this method must be such as will by irrigation be increased in selling value at least $50 or $60 per acre per year, which will be required to pay taxes, interest at 6 per cent on the cost of pumping equipment and distribution system, 7 per cent for depreciation of plant, and the upkeep and operation expenses.

SITES ADAPTED TO SURFACE IRRIGATION

Surface methods of irrigation are of four general types—furrow, flooding, check, and border—all of which are used extensively in the arid sections of the Western States.[2] Except in the irrigation of rice and cranberries, only the furrow and flooding methods are used in the East. The furrow method is used for the irrigation of cultivated row crops and orchards. The citrus groves of Florida are irrigated by this method. Many farms use a combination of the spray and furrow methods. In such cases spray irrigation is applied to seed beds, quick-growing market-garden crops, berries, and crops grown on rolling lands which are not well suited to surface irrigation; while the furrow method is used for crops on even slopes which are cultivated with horse or tractor-drawn implements.

The flooding method is seldom used since small-grain crops and meadows, to which this method is best adapted, are not ordinarily irrigated. This method requires a nearly level ground surface, and eastern soils seldom are deep enough to permit of much grading. However, if fields can be leveled properly and water can be applied cheaply enough, there is no reason why the flooding method should not be used.

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[1] Farmers' Bulletin 1529, Spray Irrigation in the Eastern States, describes in detail the construction of small or moderate-sized systems.

[2] Farmers' Bulletin 864, Practical Information for Beginners in Irrigation.

The uniformity of water distribution possible with the spray system can not be had with the surface methods, and the labor required in watering a field by the latter methods usually is much more than that required by the former.

THE WATER SUPPLY

In the East it usually is not practicable to divert water directly to the land from a stream, as is done frequently in the West, because such a diversion must be made at a point far enough upstream to permit the water to flow down the ditch to the land to be irrigated. Often this would require a ditch of considerable length, and where the land which must be crossed by the ditch is of much value or belongs to other persons the obstacles in the way of constructing a gravity supply system are serious. A pumping plant, therefore, usually is necessary for an irrigation system in the East, whether the source of supply be a well, a stream, or a lake.

Occasionally an irrigator has a choice between two possible sources of water. More frequently but one source is available, and many times investigation shows that even that one is not adequate for the plan he has in mind. In that case the entire irrigation project must be given up or the plan changed. Whether it is wise to attempt to use any given water supply depends upon a group of interrelated factors, but final decision must be controlled by the profits reasonably to be expected to result from irrigation. These expected profits will depend, (1) upon the crop to be grown—how valuable it is and how readily it responds to irrigation—and (2) upon the cost of irrigation.

The location of the water supply has an important bearing on the cost of irrigating. A long pipe line always adds materially to the expense; therefore a water-supply that is very near the field to be irrigated is generally to be preferred and is a necessity in the case of crops where the increased yield due to irrigation would be small. The height to which the water must be lifted is also important although in any going enterprise the actual cost of pumping generally is overshadowed by other costs. This is particularly true if a tractor, also used for other farm purposes, is used to furnish power for pumping, as the irrigation plant is then only chargeable for a part of the interest, taxes, and depreciation. For a water supply to be valuable in such case, it is of course necessary that the lift be not beyond the power of the tractor to raise the necessary water.

The expense of making the water supply available to the land must also be considered. The cost of a well or of building an expensive dam in a stream adds to the proper annual charges against irrigation. If a storage reservoir is needed to make a small water supply useful, its cost should also be considered.

QUANTITY OF WATER NEEDED

In the eastern or humid sections irrigation is undertaken mainly as insurance against loss from drought. Therefore it is necessary that the plants receive at each irrigation enough water to keep them in good condition for several days. About 1 inch in depth over the surface of the irrigated field, if uniformly distributed, usually meets

this need. This quantity of water is known as 1 acre-inch per acre and is equal to 27,152 gallons. Usually some losses occur in handling irrigation water, and uniform distribution is seldom possible. For this reason, more water than the quantity mentioned above must be available, and for each average irrigation about 2 acre-inches per acre will be required when a heavy soil, with considerable clay, is being irrigated, and 3 or 4 acre-inches, or even more, when a sandy soil is irrigated. In general, then, the quantity needed is from 50,000 to 100,000 gallons per acre for each irrigation.

The quantity of water required for each irrigation, once established, it becomes important to know how often these waterings must be made. This frequency varies with the locality and the season of the year in which drought occurs as well as with the crop; but for any given crop, locality, and season the greatest need for water usually comes during the hot days of summer. The number of days which may properly be allowed to pass between irrigations during the hot part of summer, in case plentiful rains do not occur, has been shown by experience to be about as follows: For green beans, Lima beans, cabbage, cauliflower, sweet corn, eggplant, mangels, peas, spinach, and home garden, 7 days; for alfalfa, potatoes, and tomatoes, 10 days; for grapefruit and oranges, 15 days. Some crops do not need irrigation at regular intervals but do require that plenty of water be supplied at certain critical periods. The following suggestions are made with reference to some of these crops: Crimson clover, one irrigation at seeding in July or August and one irrigation in the spring if very dry; field corn, one irrigation at ear-setting stage if dry; sweetpotatoes, one irrigation when vines start and one or two about 2 to 3 weeks before harvesting; strawberries, once every 3 days at time of fruiting.

The above figures indicate the periods within which the tract should be watered if the whole irrigated area is devoted to one crop. They must not be taken to mean that the shallow-rooted, delicate crops themselves require so much more water than do the deeper rooted and hardier crops but simply that the waste of water due to seepage below the root zone, and to evaporation, will be less in the case of the deep-rooted crops.

It is true that outfits that are unable to cover their entire areas within the periods given above are proving well worth while to their owners. In using equipment with such reduced capacity on a variety of crops it usually is best to apply most of the water to the more delicate or more valuable crops. It is always desirable to water thoroughly whatever part of the area is watered at all, even though the entire area may not be covered.

The number of acres to be irrigated, then, will determine the total quantity of water needed, and the time the irrigator allows for putting this water on the land will determine the quantity of water needed in a given period of time. For instance, if one wishes to irrigate 1 acre of stiff soil in one day, and to irrigate 12 hours a day, he will need about 50,000 gallons, or about 4,000 gallons per hour. If, however, he wishes to water only one-fifth of an acre a day he will need only 800 gallons per hour, or about 13½ gallons per minute. If water is scarce it may be necessary to apply water slowly and to irrigate for 10 days or two weeks. Thus, to put 50,000 gallons

on 1 acre in 14 days, irrigating 12 hours a day, one would need 50,000÷14=3,572 gallons per day, or about 5 gallons per minute. If the soil is very sandy and the land is flat, at least twice this amount will be needed. However, it is unusual to attempt surface irrigation where only 5 gallons per minute is available, unless the water can be stored between irrigations.

For a larger piece of land the quantity of water needed can be determined in the same way. For instance, if 10 acres of stiff soil is to be irrigated, it is only necessary to multiply by 10 the figures for 1 acre given above. Thus, 50 gallons per minute will be needed for 14 days of 12 hours each, but if the soil is sandy 100 gallons per minute or more will be required for the same length of time. Often it is necessary to figure on irrigating 24 hours a day as a means of using a limited water supply or of reducing the cost of pumps and piping. In such cases only about one-half of the quantity per minute required for 12-hour irrigation would be needed.

Where the water is taken from streams and can be made to flow to the land by gravity, the quantity used is not so important, and often it is desirable to use water more rapidly and to irrigate for shorter periods.

SURFACE WATER SUPPLIES

Lakes, ponds, and streams are common sources of irrigation water. One of the problems is to get the water from the source to the field to be irrigated.

In the East, it is not often that a surface-water supply can be found which is so located that it can economically be brought to the field by gravity. However, where this can be done the expense of irrigation should be small unless a costly dam in the stream or a long pipe line is required, or, in the case of a ditch, unless very rocky or high-priced land must be crossed. If it is necessary to go far upstream in order to get water at a level high enough so that it will flow to the field to be irrigated it may be cheaper to put in a pumping outfit on the bank of the stream close to the field and pump the water to the necessary level. Where the land slopes toward the stream, a long pipe line or a flume supported by trestles may be necessary. The pump should be as near the water as possible and so placed along the bank that the highest part of the land to be irrigated can be reached with the shortest possible length of discharge pipe.

If water for irrigation is taken from a lake, large pond, or large stream there is little danger of a shortage; but if the water is taken from a small stream this may not be the case. It may then be desirable to measure the flow so as to make sure that sufficient water can be obtained. Often this may be conveniently done by the use of a weir. Directions for placing a weir and making measurements will be found in Farmers' Bulletin 813, Construction and Use of Farm Weirs. Such measurements should be made in a dry period, if possible. If it is not possible to make the measurement during the time of the smallest flow, a measurement nevertheless should be made and the dry-weather flow estimated from that figure, bearing in mind that even then the low-water flow is very likely to be overestimated. Irrigation will be needed most in the driest time, and there is little to be gained by installing an expensive irrigating outfit if water is

to be lacking at that time. It must be remembered that it is the least or dry-weather flow of the stream that limits the total area that can be watered.

WELLS

Water for irrigation often is taken from wells, of which there are several kinds. Dug or open wells are used in some sections, but usually the quantity of water that can be obtained from them is too small. Being shallow, they often are dry or nearly so when water is needed most.

Drilled or bored wells frequently furnish large quantities of water. Some wells of this type flow and provide enough water to irrigate several hundred acres. Most of them, however, do not flow, although many such wells will yield plenty of water when pumped.

If the water-level in such a free-yielding well stands within suction lift of the ground surface, pumping is relatively inexpensive. In such a case the water level will not lower much due to pumping, and the machinery can be installed on the ground surface. If the distance between the operating water level and the ground surface is only a little more than the permissible suction lift, the pump may be brought within suction lift by lowering it into a suitable pit. If, however, the water level during pumping is much below practical suction lift when measured from the ground surface, a deep-well pump, which is relatively expensive, will be needed.

Before a new well is accepted from the contractor, it should be tested by pumping to full capacity for 40 to 50 hours without stopping. It is the duty of the well driller to make such a test. While the test is being made the quantity of water pumped and the draw down—that is, the lowering of the water surface due to pumping—should be measured. The quantity pumped may be measured with a weir box placed near where the water is discharged. In determining the draw down the first thing is to measure the distance that the water level stands below the ground surface when the well has not been pumped for several hours. The water level in the well should then be determined at frequent intervals while the test is being made. The water levels before and during pumping may be quite different, as a considerable draw down is to be expected while the pump is running. The draw down is the difference between the natural water level before the test was made and the lowest level found while pumping. The amount of the draw down should be known as it may have an important bearing on the type of pump to purchase and on the way the pump is placed.

The water level in the well before the test is begun may usually be found by means of a float suspended on a string. The water level in the well during the test will often have to be measured by means of a vacuum gauge. If a horizontal centrifugal pump is used for the test this may be done by connecting the vacuum gauge to the suction pipe near the pump intake. The reading of the gauge usually will be stated as so many inches of mercury. To get it into the more convenient unit of feet-of-water, multiply by 1.14. If the gauge has been placed with only a short connection so that it is close to and level with the center of the horizontal part of the pump intake, the figure so obtained is the number of feet between the center of

the gauge and the water level in the well during pumping. This number of feet will then have to be increased or decreased by the distance in feet between the center of the gauge and the ground surface (according as the gauge is below or above the ground surface) to get the distance from the ground level to the operating water level. For conditions where the above method can not readily be used, the reader is referred to Farmers' Bulletin 1404, Pumping from Wells for Irrigation.

Driven wells also are used in irrigation. They provide a cheap water supply where the distance the pump must raise the water is less than 25 feet, and the quantity of water needed is not too great. One 2-inch well will usually yield from 10 to 40 gallons per minute if the point is driven into good water-bearing sand or gravel. A

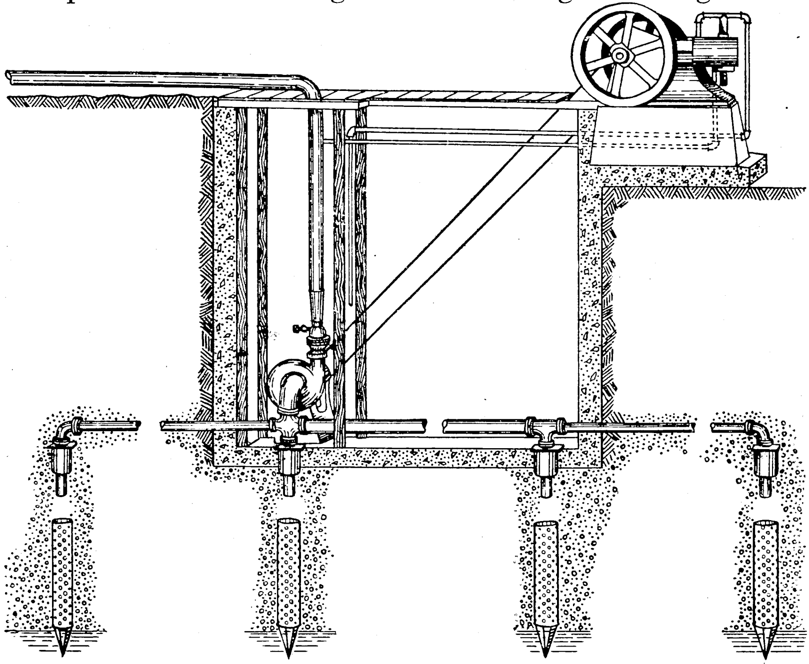

FIGURE 1.—Horizontal centrifugal pump set in concrete pit, to pump from several connected wells. The pit is required because the suction lift from the ground surface is too great

number of points may be driven from 10 to 20 feet apart and connected to one central pump. If the water level is slightly more than 15 feet below the ground surface, the same method often can be followed by digging trenches, laying the connecting pipes in them, and setting the pump in a central pit. The pit and connecting trenches (fig. 1) must be deep enough to bring the water level well within suction lift when the pump is running.

THE PUMPING PLANT

The pumping plant consists of the pump and engine or motor which drives it. For such irregular service as is required for most eastern irrigation plants the best pumping outfit is one that is rugged

and durable, and that will do its work under all conditions with very little attention. Where there is danger of floods, as on a river bank,

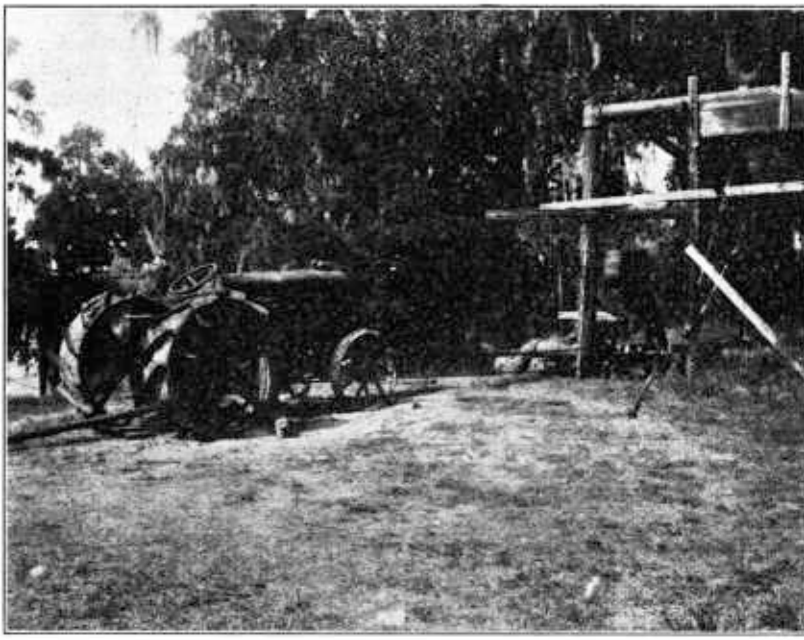

FIGURE 2.—Tractor and centrifugal pump delivering water to wooden flume

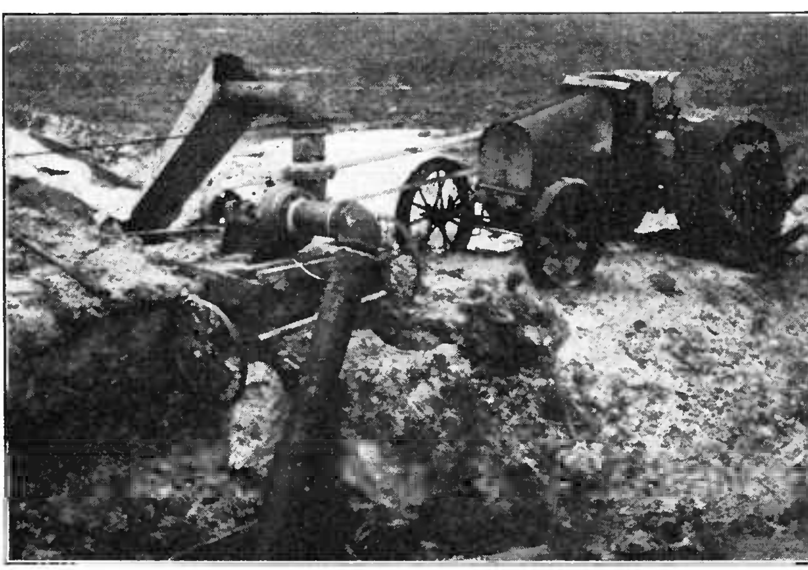

FIGURE 3.—Tractor and centrifugal pump delivering water to open ditch

it is best to place pump and engine on skids or wheels so that they can be moved quickly and easily. Tractors are well suited to furnishing power in such cases. (Figs. 2 and 3.) Some irrigators,

however, prefer to install centrifugal pumps permanently even under such conditions and let the high waters cover them. The pump shown in Figure 2 was so installed and has been flooded several times. Plunger pumps never should be so placed as to be subject to flooding, particularly if the water is muddy.

THE PUMP

Where surface water is used a centrifugal pump usually is the cheapest and most suitable for irrigation in the East. In this form of pump the rotating shaft carries a system of curved blades known as the impeller. The impeller is inclosed in a water-tight shell or chamber of cast iron. Rapid rotation of the impeller sets up sufficient motion or velocity in the water to drive it through the discharge pipe. The advantages of the centrifugal pump are low cost, simple design, light weight, lack of valves that wear out quickly, ease of operation and repair, and high efficiency in raising large quantities of water through moderate and fairly high lifts.

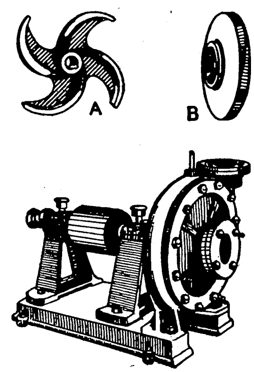

FIGURE 4.—A centrifugal pump showing both open type (A) and closed type (B) of impeller

Centrifugal pumps are made in two general types, the horizontal type (having a horizontal shaft) and the vertical type (having a vertical shaft). Each of these types is made in both the open-impeller and the closed-impeller forms. The difference in these types is clearly shown in Figure 4.

A centrifugal pump with one impeller is known as a single-stage pump. One with two impellers is called a 2-stage pump. Centrifugal pumps are made in several stages. The number of stages required depends upon the height to which the water must be lifted. The ordinary single-stage pump with the open impeller is made to raise water through a total lift of about 40 feet, and this can be done at a moderate speed. By adding more stages the height can be increased, the speed remaining the same, but the cost of these pumps rises rapidly with the number of stages. Single-stage pumps built for high lifts and high speeds may be had, but they cost more than the low-lift and slow-speed pumps and must have more careful attention.

The single-stage horizontal (figs. 1, 2, and 7) type of centrifugal pump is the one most commonly used for irrigation, it being especially suitable for pumping quantities of water above 250 gallons per minute, from streams or from wells where the suction lift is not too great. This pump is made both as a cheap and as a high-grade pump. The cheaper open-impeller pump can be expected to operate satisfactorily where the suction lift is not over 4 feet. It may work well at somewhat higher lifts, but the chances of satisfactory operation decrease as the lift increases above 4 feet. The practical suction lift for the high-grade inclosed-impeller pump is about 15 feet. If the water in the well is at a depth somewhat more than the suction lift the pump can usually be set in a pit and belt-connected to an engine or motor at the ground surface. As a rule a pump can not be operated satisfactorily in a pit more than 15 feet deep.

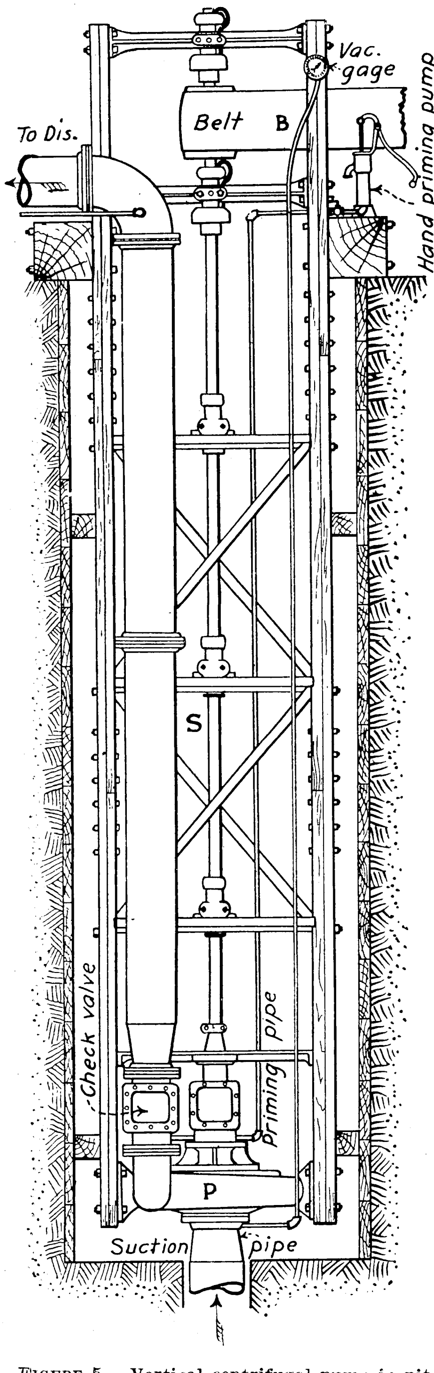

FIGURE 5.—Vertical centrifugal pump in pit. Pump P is operated through vertical shaft S by means of half-turned belt B

The vertical centrifugal pump is also used for irrigation. (Fig. 5.) In this pump the impellers are operated by a vertical shaft which may be of considerable length. The vertical type is used mostly for pumping from wells where the water level is so low that it can not be lifted to the ground surface by suction. The pump may be set in a deep pit below the groundwater level and run by a belt-driven pulley on top of the vertical pump shaft. Vertical centrifugal pumps cost about 50 per cent more than horizontal pumps of the same capacity and use about 10 per cent more power. To the cost of the pump itself must be added the cost of the pump pit and of the framework which holds the vertical shaft.

Where the suction lift is so great that hand-dug pits can not be used, a type of centrifugal pump known as the deep-well turbine pump (fig. 6) is employed. These pumps are so made that they can be let down to any depth in drilled wells of suitable bore. Deep-well pumps of large capacity cost from five to ten times as much as horizontal centrifugal pumps of the same capacity. To the cost of the pump must be added the extra cost of boring and casing the larger well made necessary by its use. Deep-well pumps are efficient when delivering 500 gallons per minute or more and give little trouble if properly installed. Except for rice fields, very few are used for irrigation in the Eastern States.

Centrifugal pumps used for farm irrigation usually are fitted with pulleys and are

belt-driven by gasoline engines, farm tractors, or electric motors. (Figs. 3, 4, and 5.) This is generally the best arrangement when tractors are used or when the pump must be set in a pit which at times is flooded. Where there is no danger of flooding, and pump and engine are not used for other purposes, direct-connected outfits (fig. 7) are to be preferred because there is no belt slippage and the system is more compact.

In choosing a pump for irrigation service a rugged, well-built machine should be selected. In the Eastern States irrigation pumps are used so few hours each year that the efficiency is of little importance as compared with reliability of operation. However, in certain cases a high-grade, efficient pump may be a better one to buy, as owing to its greater efficiency it may be possible to drive it with a smaller engine or motor and by this means justify its increased first cost and the more careful attention that must be given to it. Particularly is this true when such a pump makes it possible to use an engine or tractor already on hand.

Centrifugal pumps are designed for certain fixed lifts and work most efficiently at those lifts. The efficiency decreases if the pump is operated against a total head that differs from the designed head by only a small amount. For this reason the choosing of the right pump for the work to be done is important, and the dealers from whom cost estimates are asked should be given full information as to the lift and other conditions, and the specifications should be followed closely in installing the pump.

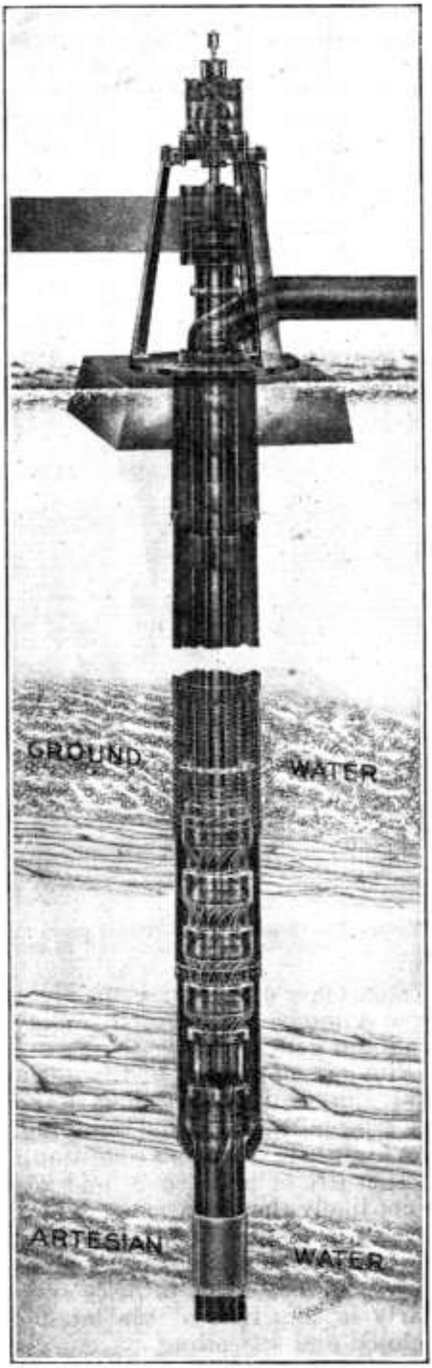

FIGURE 6.—Deep-well turbine pump, operated by half-turned belt

The air-lift pump (fig. 8) is another means of raising water from deep wells. It is a simple arrangement of piping whereby the water may be raised by compressed air. There are no working parts, and no valves except to regulate the supply of air. Besides the air compressor and power unit, the equipment consists of a drop pipe placed in the well with its lower end under water, and a small air line which carries the compressed air to a point near the lower end of the drop pipe. At this point the compressed air is discharged into the drop pipe, through a suitable outlet called the foot piece. Since the mixture of water and air in the drop pipe is lighter than the water outside the pipe which contains no air, the mixture rises to the ground surface. While the air lift is simple, it nevertheless must be correctly designed. The sizes of pipes and foot piece must be rightly proportioned, and the foot piece must be properly submerged.

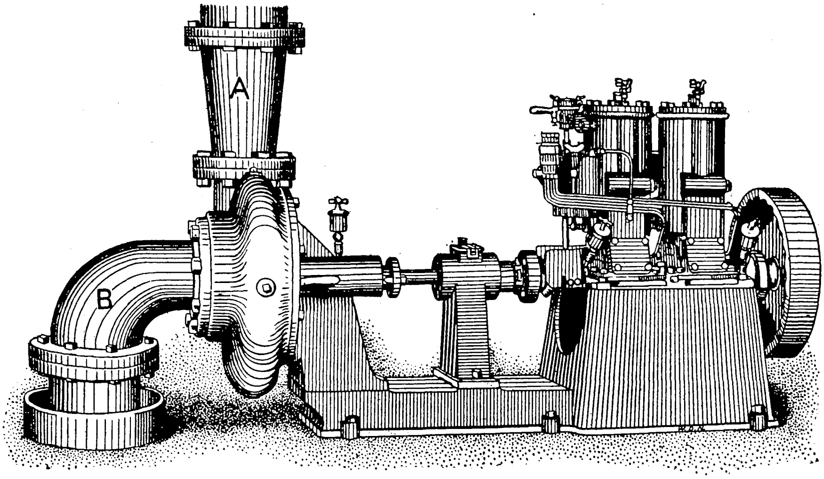

FIGURE 7.—Horizontal centrifugal pump direct-connected to 2-cylinder marine engine. A shows discharge and B suction pipe. Note taper of both

This type of pump is particularly suitable for pumping water from a number of scattered wells and for handling water containing sand and grit.

Plunger pumps are of three general types: Simplex (single cylinder), duplex (two cylinders), and triplex (three cylinders). They are especially useful for pumping from wells when the suction lifts are high. If in good condition, a plunger pump has a practical suction lift of between 20 and 25 feet. Owing to their high cost it is not likely that many new duplex or triplex pumps will be used for irrigation in the East, but for pumping up to 100 gallons of water per minute the double-acting pump with a single horizontal cylinder (fig. 9) is reasonable in price and satisfactory in operation. Particularly is this true of the latest forms of these pumps which are inclosed and self-oiling.

THE POWER UNIT

With the increasing use of electricity on farms electric motors will, without doubt, come into more general use for operating irrigation pumps, as they are so easily started, require little attention, and their first cost in sizes up to 15 horsepower is about that of gasoline engines of equal power. Above 15 horsepower the cost of the electric motor is generally less than that of the gasoline or

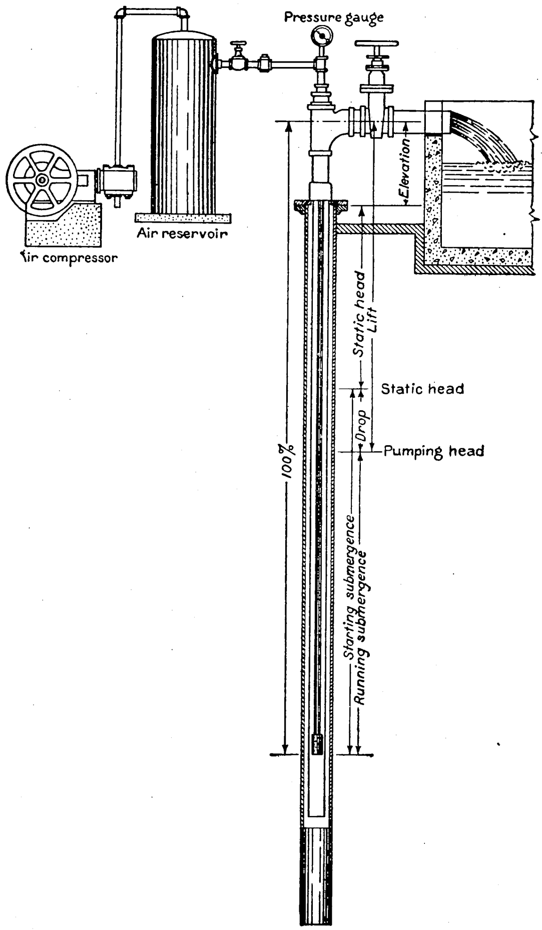

FIGURE 8.—Air-lift pump

kerosene engine. Owing to the shortness of the irrigation season and to the fact that pumping is done only occasionally, the cost of electric power with the considerable attendant charges made has, up to this time, generally been so high that comparatively few electrically driven plants have been used. Where the total charges are not too great, however, the electric drive proves satisfactory in every way.

If an electric pumping unit is used for pumping from a well where the suction lift from the ground surface is too great, the unit is sometimes placed in a pit at such a depth that the suction lift is not excessive. This arrangement, however, is not considered good practice owing to the dampness in the pit which is likely to destroy the insulation and damage the motor. A motor with windings protected with special moisture-proof compound should be used in such a case.

At the present time the most common source of power used in small irrigation plants in the East is the gasoline engine. (Figs. 7 and 9.) Many kerosene engines are used, however, as well as a few engines that burn the heavier fuel oils. Engines using gasoline, kerosene, and fuel oil are known as internal-combustion engines. Those using gasoline are generally of the smaller sizes.

It is very important that the engine be suited to the work to be done. The internal-combustion engine is not adapted to carrying heavy overloads; therefore an engine with sufficient power to handle the greatest pumping load that will be placed upon it should be

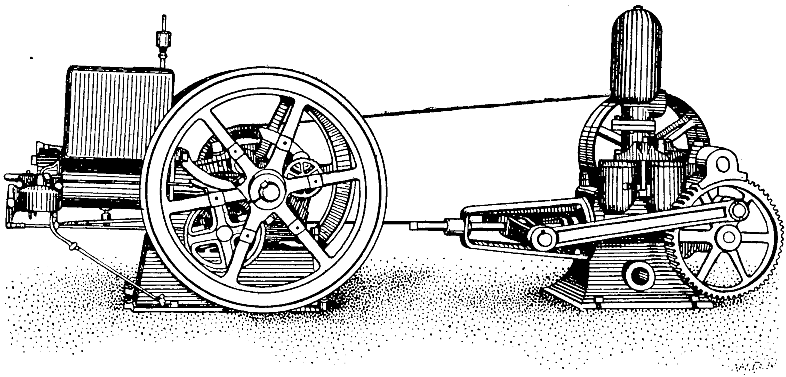

FIGURE 9.—Gasoline engine belt-connected to single cylinder, double-acting plunger pump

chosen. When crops need water they should be irrigated immediately. A reliable engine therefore is necessary—one that can be depended upon to start quickly and run steadily. In this connection the ignition system is important; one that will hold its adjustment for long periods without attention is very desirable. Sturdy, slow-speed engines which are easily lubricated generally give the best service for farm irrigation.

Engines suitable for eastern irrigation, ranging from 6 to 25 horsepower, can be purchased for about $20 per horsepower. More powerful engines cost somewhat less per horsepower, while those of smaller capacity cost slightly more.

Sometimes second-hand automobile engines have been used for pumping, but unless good judgment is used in selecting the engine and in adapting it to the particular service in view it is likely to prove unsatisfactory.

The engine used with an irrigation plant often may serve other purposes, especially if it can be moved easily. The tractor therefore is particularly suited to this service. If the engine is already being

used on other work when the pumping plant is installed, the pump selected must be suited to the engine.

The size of the pump depends upon the time allowed for irrigating. The horsepower of the engine to operate the pump depends upon the quantity of water to be lifted, the height of the irrigated land above the water source, and the distance the water must be carried in a pipe. Table 1 shows the quantities of water needed to irrigate different acreages, the sizes of the pump, and the power necessary to irrigate those acreages. The total horsepower required may be found by multiplying the number found in Table 1 (column 9) by the total number of feet-of-lift. This total lift will be the lift from the water surface to the highest part of the land to be irrigated, plus the loss due to friction. The friction loss depends upon the size and length of pipe. This loss is shown in column 7 of Table 1 in feet of head per 100 feet of discharge pipe.

TABLE 1.—*Sizes of pumps and engines required for the irrigation of different areas*

Area	Water required per 2-inch irrigation	Capacity of pump per minute	Size of pump [1]	Kind of pump	Size of discharge pipe	Friction loss in discharge pipe per 100 feet	Efficiency of pump	Horsepower of engine per foot of lift	Approximate cost of pump [2]	
									20 to 40 feet lift	40 to 100 feet lift
Acres	*Gallons*	*Gallons*	*Inches*		*Inches*	*Feet*	*Per cent*		*Dollars*	*Dollars*
¼	13,500	10	3 by 4	Single-cylinder double acting plunger.	1½	1.43	30	0.01	75	75
½	27,000	10	do	do	1½	1.43	30	.01	75	75
1	54,000	20	4 by 4	do	2	1.82	30	.017	90	90
2	108,000	35	5 by 5	do	2½	1.72	30	.029	120	120
3	160,000	35	do	do	2½	1.72	30	.029	120	120
4	210,000	55	6 by 6	do	3	1.6	35	.040	165	165
5	270,000	110	6 by 12	do	4	1.45	40	.070	220	220
			No. 2	Centrifugal	4	1.45	30	.093	40	100
10	540,000	225-265	No. 3	do	6	0.74-1.06	35	0.166-.195	65	110
15	800,000	300-375	No. 4	do	6	1.29-2.00	40	.185-.231	80	150
20	1,000,000	400-500	do	do	8	.56-.81	40	.247-.309	80	150
25	1,300,000	700-750	No. 5	do	8	1.54-1.74	45	.39-.418	100	250
30	1,500,000	700-750	do	do	8	1.54-1.74	45	.39-.418	100	250
40	2,000,000	900-1,100	No. 6	do	10	.83-1.20	50	.456-.558	115	350
50	2,700,000	900-1,100	do	do	10	.83-1.20	50	.456-.558	115	350
75	4,000,000	900-1,100	do	do	10	.83-1.20	50	.456-.558	115	350
100	5,400,000	1,200-1,500	No. 8	do	12	.57-.85	55	.55-.68	235	500
200	10,800,000	1,600-2,200	do	do	12	1.00-1.78	55	.73-1.0	235	500

[1] Plunger pumps are rated by diameter of the plunger in inches, and the length of stroke in inches, which are the dimensions shown here. Centrifugal pumps of the cheaper grades ordinarily recommended for eastern irrigation for total heads up to 40 feet, are sold by number, which describes the diameter of the discharge pipe, in inches, at the pump. In the case of centrifugal pumps of the better grades and for the higher lifts, each pump is fitted to its work and the number of gallons per minute handled, rather than size of pump, governs. Purchasers should obtain a manufacturer's guaranty that the pump actually has the capacity represented under the given conditions.

[2] Prices are those quoted in 1929.

The figures in Table 1 apply to fairly stiff soils and to localities where the slopes of the land are such that the water can be handled without excessive waste. They allow for a total pumping capacity of 50,000 gallons per acre for one full irrigation. For a sandier soil—say where 100,000 gallons per acre is required—the figures in columns 2 to 11, inclusive, should be taken as for twice the acreage given in Table 1. Thus for 10 acres of a soil that is quite sandy the figures would be those given in Table 1 for 20 acres. In like

manner, for the types of soil that range between fairly stiff and quite sandy, the figures given in the table should be revised proportionately.

To illustrate the use of Table 1, suppose it is desired to irrigate 10 acres of fairly stiff soil under favorable conditions of slope. Suppose the highest point of the land to be 40 feet above the water supply, and that the pipe line from the pump to the land to be irrigated is 1,200 feet long. From the table it is seen that a No. 3 centrifugal pump will be needed. To find the horsepower necessary to operate the pump, determine first the total lift, which will be the difference in elevations, 40 feet, plus the friction loss. If 6-inch pipe is used, the friction loss, according to the table, will be 0.74 foot of lift for each 100 feet of pipe, assuming that the pump is operated at its lower capacity, 225 gallons per minute. There being 1,200 feet of pipe, the friction loss will then be $12 \times 0.74 = 8.88$ feet, so that the total lift will be $40 + 8.88 = 48.88$ feet. The total horsepower called for will then be $48.88 \times 0.166 = 8.11$, this being at the rate of 0.166 horsepower per foot of lift. A 10-horsepower engine would be recommended for this plant.

It would be possible to use smaller discharge pipe than the sizes recommended in Table 1, but if that were done more power would be required to force the water through it. Where conditions require the use of pipe smaller than shown, the matter of specifications should be referred to the pump or engine manufacturers, or to the United States Department of Agriculture.

The foregoing paragraphs and Table 1 will enable one to decide as to the kind and size of pump and power unit he will need, so that he can estimate the cost of this equipment. However, before a pump is purchased for an irrigation plant, any manufacturer whose product is being considered should be given full information as to the pumping requirements. These will include the number of gallons of water required per minute, the total pumping lift, whether the source of supply is a well or an open body of water, whether a belt connected or a direct-connected pumping unit will be needed. Of these items, the total lift is very important, and it is often the most difficult to estimate.

Unless a qualified engineer is employed to determine the lift, it is probably best to leave it to the manufacturer to estimate. To do this he will need to know the difference in elevation between the water level to be pumped from, and the open end of the discharge pipe; the size and length of suction pipe and discharge pipe; the number and kinds of fittings, including bends and reducing and enlargement fittings; also whether a foot valve is desired at the lower end of the suction pipe. If water is to be taken from a well, the manufacturer should be informed of the draw down (see p. 6) in the well when pumped to capacity, and the number of gallons per minute the well supplied under these conditions It would also be well to inform the manufacturer that the outfit is desired for eastern irrigation conditions and that therefore it would be operated for only a few days each year.

With the above information any pump manufacturer should have no trouble in deciding on a suitable pump to offer for the job, and in determining the horsepower necessary to drive it. A pump should be purchased only against a satisfactory guarantee that it

will deliver the required number of gallons per minute when installed under the conditions named. It should not be paid for until it has been installed and tested and found to deliver water at that rate when driven by an engine or motor of the specified size. The easiest way to measure the quantity of water delivered will generally be by means of a weir (see p. 5) placed at some point near the open end of the discharge pipe.

INSTALLING THE PLANT

Generally the pump should be located as near the source of water supply as possible. Several arrangements of the pump and power unit are shown in Figures 1, 2, 3, 7, and 9.

The pump and engine should be placed upon a level and solid foundation, or upon two separate foundations if necessary. For the smaller engines and pumps, heavy wooden foundations will do. But for all permanent settings for medium-sized and large pumps and engines, good concrete foundations should be built, and they are much better even for the smaller ones. In constructing such a foundation for a pumping unit, or for pump and engine separately, the concrete base should be prepared with its top surface about one-half inch lower than the level at which the pumping unit is to be set. This is to allow for the final leveling and grouting as described later.

Upward through this foundation surface should project the threaded ends of the anchor bolts which are to hold the machinery in place. The threads on these bolts should be extended farther along the stem than is customary, and the bolts should stick up an inch or two farther than they are likely to be needed. They should be so located that when the machine is in place they will extend up through the bolt holes or slots of the bedplate far enough to receive the washer and nut. The head ends of the bolts, projecting through large-sized washers, should be set in the concrete with ordinary pipe thimbles large enough to allow a ⅜-inch or ½-inch clearance all around the bolt. The manufacturers of the pump and engine will furnish plans showing accurately the location of these foundation bolts, so that the foundation may be placed before the machinery arrives.

A 1:2:4 concrete (1 part of Portland cement, 2 parts of clean sand, and 4 parts of crushed rock or gravel) makes a good material for such a foundation if properly mixed and cured. Directions for mixing concrete are to be found in Farmers' Bulletin 1279, Plain Concrete for Farm Use.

After the concrete base has hardened, place the machinery upon it, bring it to the desired elevation and level it carefully in every direction by wedging under the bedplate. Now see that the revolving parts turn over easily. With a centrifugal pump it will generally be necessary to loosen the packing in the stuffing box. Do not, however, obtain ease of turning by loosening the bearings. When all strain is removed and the machinery is level, the rotating parts should turn easily. Fill in between the bedplate and the concrete base with the one-half inch or so of grouting that will be needed to give the bedplate a good bearing all around. This grouting may be made of a mixture of equal parts of cement and sand, with enough

water to make it work easily. When this has hardened tighten the foundation bolts, being careful not to spring the bedplate. After the bolts are tightened it is important that the rotating parts should still turn easily by hand. Be sure that this is the case. Again, after the piping has been attached to the pump it should be tested for ease of turning.

The whole pumping outfit should be protected from the weather and from dust and dirt. It should be housed in a building or room not used for any other purpose, and be so placed within this room that both pump and driver are easy to get at from all sides. If the power unit is a gasoline engine, the ignition system is likely to give the most trouble. Great care should, therefore, be given to its adjustment, and it should be carefully protected from moisture and dirt. If the power unit is an electric motor the windings must be kept dry. Before freezing weather sets in each winter all water should be drained from the pump and pipes, inside as well as outside the pump house.

PIPE AND FITTINGS

The pipe on both the suction and the discharge sides of the pump should be large enough to reduce friction loss as much as possible. The pipe used should never be smaller than the pump tappings, and for long lines they should be from one to two sizes larger. Great care must be used in tightening joints to see that no strains are put on the machinery.

All pipe lines should run as directly as possible and have no unnecessary bends. As a large part of pump trouble is found on the suction side, great care should be used to see that this is properly installed. As before stated, the pump must be well within the suction lift of the operating water level and a suction pipe at least one size larger than the pump intake tapping is desirable. The reduction in size of the suction pipe should be made at the pump connection, preferably by the use of a tapered fitting. (Fig. 7.) Such fittings may be obtained from the pump manufacturer. The joints must all be tight, as an air leak is fatal to good operation. If the pipe is not dropped directly downward from the pump into the water supply, it should at least be so sloped that there will be no pockets where air can collect. The lower end of the suction pipe should extend far enough below the water surface so that air will never be drawn in. For a small outfit pumping from a large body of water a 2-foot submersion will be ample. For larger pumps 4 feet or more will be needed, and when pumping from a sump or collecting chamber even greater submersion may be necessary, owing to the tendency of the water to cup down over the intake. In pumping from a well where a drop pipe is used, the lower end must be far enough below the water surface to make full allowance for the lowering of water level due to pumping. If pumping is to be from surface bodies of water a well-made strainer with ample openings should be provided to keep sticks and trash from being drawn into the suction pipe and thence into the pump.

On the discharge side of the pump the pipe may be of the same size as the pump fitting if only a few feet in length; if longer, it should be enlarged, and this should be done as near the pump as

possible, preferably through a tapered fitting. (Fig. 7.) The discharge pipe also should have as few bends as possible.

It is necessary to install certain valves and piping on the main water pipe lines around the pump. These valves are used in priming the pump and for protecting it from very high water pressures that may be set up accidentally. Where the discharge pipe is long a check valve should be placed in it near the pump. To protect a plunger pump a pressure-relief valve is desirable and always should be provided on the discharge side of a large pump of this type. When both a check valve and a pressure-relief valve are used, the former should be nearest the pump.

Before starting a centrifugal pump it is necessary to prime it. A common way of providing for priming, if the discharge pipe is short, is to place a gate valve in the discharge pipe, or a flap valve at its end, and a common hand pump at the pet-cock tapping in the top of the pump chamber. By operating the hand pump, with the valve closed, the air is exhausted from the suction pipe and pump chamber, and the pump filled with water. If the discharge pipe is long, it is only necessary to pump the air from the suction pipe and pump chamber, since the check valve (mentioned in the preceding paragraph) is automatically closed.

Another way of priming is to set a foot valve in the lower end of the suction pipe and then to fill the suction pipe and pump chamber with water from a barrel or tank placed at a suitable height. After the first priming each season this supply tank may be filled by a small branch pipe taking water from the discharge pipe. No hand pump is needed in this case, but it is very important that the foot valve have a water passage large enough for the regular pump operation.

Do not run a centrifugal pump empty, as water is depended upon for lubrication, and lack of lubrication even for a short time may injure the pump. Such a pump must be primed each time before starting. A gate valve in the discharge pipe near the pump, in the case of a centrifugal pump, is often necessary where there is difficulty in bringing the pump up to speed. Such a valve should be placed on the discharge side of the check valve. A by-pass suitably valved is a convenience with a plunger pump if there is difficulty in getting up speed.

BRINGING THE WATER TO THE LAND

DITCH SYSTEMS

If the water supply is to be brought to the field through an open ditch, the proper size of the ditch and its fall should be determined before excavation is begun. The size of the ditch will depend principally upon its slope and the acreage to be watered. Usually the grade is kept as flat as possible, both to prevent washouts and to deliver the water at a good elevation. If water is taken from a gravity supply and the diversion point on the stream is high the fall of the ditch often will depend upon the kind of soil. If the grade is made very steep in order to cut down the size of the ditch, trouble from washouts is likely if the soil is sandy or if the ditch is carried along a hillside. However, it is possible to protect such a ditch by lining it with concrete. Where there is no danger of injury through freez-

ing such a concrete lining may be a thin, plastered coating put on with a trowel, or a thicker lining may be applied if it seems necessary. Every effort should be made to so locate the ditch that it will be in the ground instead of on fills.

A small ditch can safely be carried on a steeper fall than a large one. Table 2 gives the quantities of water that ditches of various sizes and fall will carry safely in soils not classed as sandy. In sandy soils the side slopes of the ditches described in Table 2 might not stand. In that case it would be necessary to make the ditch wider and shallower, and with a slightly greater cross section in order to carry the same amount of water at the same grade. To aid in doing this, the cross-sectional areas of ditches of different sizes are given in Table 2 for making comparisons. The distribution ditches should be located on the higher parts of the field to be irrigated, either along its high side or along the tops of the ridges that may extend into it.

TABLE 2.—*Carrying capacities of ditches*

Size of ditch	Fall	Carrying capacity	Size of ditch	Fall	Carrying capacity
	Inches per 100 feet	*Gallons per minute*		*Inches per 100 feet*	*Gallons per minute*
Top width 2 feet, bottom width 1 foot, depth 6 inches, cross-sectional area 0.7 square foot.	4	340	Top width 4½ feet, bottom width 2½ feet, depth 1 foot, cross-sectional area 3. 5 square feet.	1	1,460
	6	410		1½	1,790
	8	480		2	2,070
	12	590		3	2,550
	18	720	Top width 5½ feet, bottom width 3 feet, depth 1 foot 3 inches, cross-sectional area 5.3 square feet.	1	2,620
Top width 3 feet, bottom width 1½ feet, depth 9 inches, cross-sectional area 1.7 square feet.	2	760		1½	3,220
	3	930		2	3,730
	4	1,070	Top width 7 feet, bottom width 4 feet, depth 1½ feet, cross-sectional area 8.2 square feet.	¾	4,150
	5	1,200		1	4,800
	6	1,320		1½	5,900
Top width 3 feet, 8 inches, bottom width 2 feet, depth 10 inches, cross-sectional area 2.3 square feet.	2	1,190		1¾	6,380
	3	1,460	Top width 9 feet, bottom width 5 feet, depth 2 feet, cross-sectional area 14 square feet.	⅜	6,080
	4	1,690		½	7,070
				¾	8,700
				1	10,070

To handle the water as it comes from the larger supply ditches, several small structures are needed. It may be well to use wooden structures until the system has been tested thoroughly.

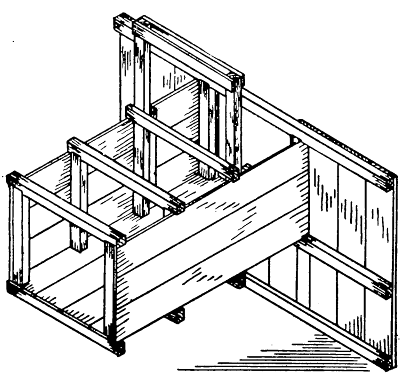

FIGURE 10.—Wooden head gate with one outlet

A wooden head gate usually is put in where a small ditch is taken from a main. Such a structure (fig. 10) may have 1, 2, or 3 outlets. The water is controlled best by means of movable boards fitted into cleats nailed to the side of the box. Small ditches, however, generally call for such structures only at the intake. At other points the water may be controlled either by filling the ditch with dirt at the proper places, and cutting the bank with a shovel or by using canvas or sheet-iron dams that can be

moved around as desired. (Fig. 11.) In using the canvas dam the irrigator places the top slat across the ditch and throws a little dirt on the canvas at the bottom and sides. The sheet-iron dam is merely thrust into the ditch deep enough to stand the pressure of the water against it.

The common way to take water from a small ditch at the heads of the furrows is to cut small trenches through the side of the ditch with a hoe or a shovel. A better method calls for the use of lath spouts or pieces of pipe placed in the banks of the ditch. (Fig. 12.) The quantity of water let into each furrow may be regulated either by a cloth flap over the intake end of the lath spout, or preferably by means of a small tin or galvanized sheet-iron gate or slider. Where a pipe spout is used water may be controlled by means of a single thrust into the earth in front of the pipe.

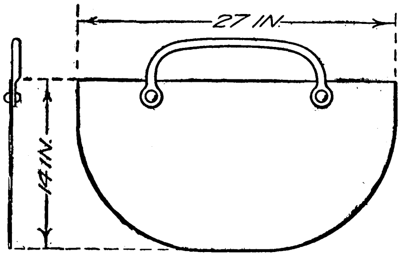

FIGURE 11.—Metal dam or tappoon

VITRIFIED SEWER-PIPE SYSTEMS

Under some conditions a satisfactory distribution system may be built of vitrified clay sewer pipe, also called terra-cotta pipe or salt-glazed pipe. This pipe can be made water-tight under low pressure and can be laid by anyone who is willing to use the necessary care. A sewer-pipe line should not be used for a vertical head of water of more than 15 feet, which means a pressure of 6 pounds per square inch. It may be laid over ridges and across depressions if the total safe head is not exceeded. As is done with open ditches, distribution pipe lines are laid along the highest side of the land to be irrigated, and the water is let out at convenient points. Often it is possible to lay the pipe on top of a ridge across a field and run the water down both slopes.

None but the best grade of sewer pipe should be bought for this use. Pipe with cracks or broken ends should be rejected. The best way to test for cracks is to tap the pipe lightly with a hammer, a clear ring usually meaning a sound pipe. Pipe which is not well formed also should be rejected.

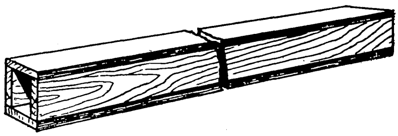
FIGURE 12.—Lath pipe for ditch bank

The trench in which the pipe is laid should be dug deep enough to allow at least 18 inches of earth cover over the pipe after it is laid. This is to prevent injury to the buried pipe when a heavily loaded wagon or a tractor passes over it. The bottom of the trench should be scooped out to a rounding surface to bed the pipe properly. This is most easily done by digging a flat-bottomed trench and then scooping out a central channel with a tile scoop to a depth of one-third the outside diameter of the pipe. (Fig. 13.) The flat-bottomed part of the trench should be dug about a foot wider than the outside width

of the pipe to allow the worker to move about in the trench without disturbing the pipe previously laid. As the pipe is laid hollows should be scooped out for the pipe bells so that a considerable part of each pipe will bed firmly in the trench. (Fig. 13.) In back filling the trench the earth should be carefully tamped around the pipe.

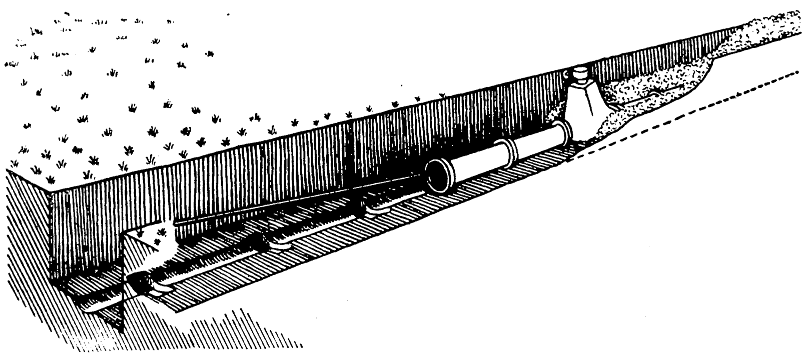

FIGURE 13.—Installing vitrified sewer-pipe distribution system

Joints may be made either with cement mortar or with bituminous sewer-pipe joint compound. Most irrigators now use both materials, making one to four joints of the compound and then one of cement mortar. The advantage of this is that the bituminous compound is elastic enough to allow some give in the pipe line due to settling, temperature changes, etc. Also, farm workers seem better able to make good cement joints than bituminous joints, when the pipe is lying in the ditch. The method usually followed is to join two to five lengths of pipe outside the ditch and then lay the assembled unit. These units are readily made by stacking the lengths in a vertical position, bell ends upward, and pouring the melted bituminous material into the joints. Before pouring, however, the lower part of the space between the bell of one pipe and the spigot of the next should be well calked (fig. 14) to prevent the melted joint material from running out and wasting. For calking, jute often is used but pieces of newspaper crumpled up and carefully tamped into place answer very well.

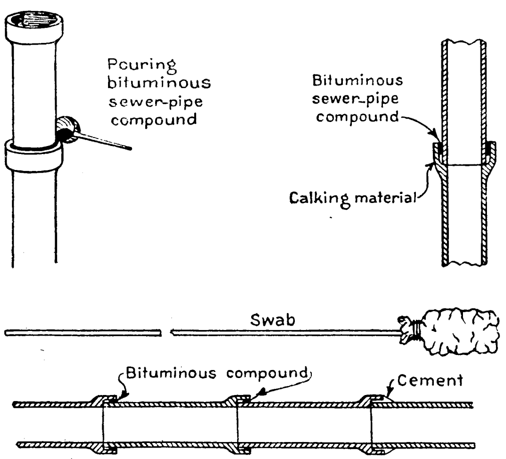

FIGURE 14.—Method of assembling vitrified sewer-pipe unit

Better joints are required for this work than for ordinary sewer work. Therefore not over one-third the depth of the bell should be filled with calking material, at least two-thirds being left to be filled

with the joint material. The heavier grades of bituminous sewer-pipe joint compound should be used, the grade that weighs about 108 pounds per cubic foot being very satisfactory. About one-fourth pound per inch of pipe diameter will be needed for each joint. The material should be melted in a kettle and heated until it pours like water. It is important, however, not to heat it above that point. A skillet or ladle may be used for pouring.

After the joints have cooled the assembled units of several pipe lengths may be laid. But before this is done the bell holes should be scooped out of the trench. The correct locations for the bell holes may be most conveniently spotted by the use of a straight stick properly marked off.[3]

When the new pipe unit is in place it should be joined with a water-tight joint, usually of cement mortar, to the pipe already in place. For good cement joints it is important that the entire joint space be filled with the cement mortar; this requires that the mortar be tamped firmly into the bell. Great care should be taken to make sure that the under side of the joint is well cemented. To do this effectively it often is necessary to use a tamping tool. Such tools may be made of iron, but very satisfactory ones can be whittled out of wood. To smooth up the inside of the pipe in case any mortar works into it, a long-handled swab (fig. 14) made of gunny sacking so as to fit the inside of the pipe should be provided. This swab is allowed to lie in the pipe with its handle projecting outside as shown in Figure 13. When a secton of pipe is added it is slid over the swab handle, and the swab is always drawn toward the open end of the pipe.

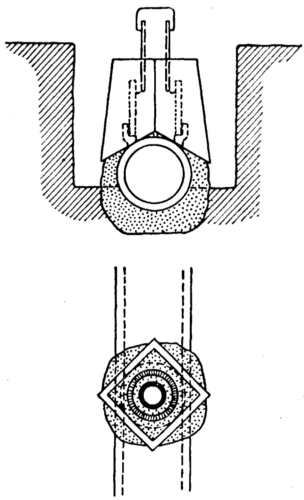

FIGURE 15.—Nipple and cap outlet from vitrified sewer-pipe distribution line

The mortar for the joints should be made of clean, sharp sand mixed with an equal quantity of cement and only enough water to make the mixture fairly stiff. Only small batches should be mixed at a time, and these should be used quickly; it is not wise to use mortar that has stood longer than 15 minutes.

The outlet valves or hydrants are commonly spaced from 30 to 100 feet apart and are connected by short lengths of clay pipe to standard sewer-pipe tees placed in the main pipe line as it is laid. Each outlet is cemented firmly to its short riser pipe. In the best class of work a block of concrete is then cast around the tee and its short pipe, thus reinforcing the entire connection with the main. (Fig. 13.) Where the soil is likely to freeze, this block of concrete should always be tapered toward the top, to guard against heaving.

Four-inch iron pipe nipples for outlets, and 4-inch cast-iron pipe caps to shut the water off when it is desired to close the outlets (fig. 15) are sometimes used. Such openings are cheap, but the

[3] One contractor who has done a considerable amount of this work beds the pipe with the aid of water instead of scooping out for the bells. After the pipe is laid and the joints tested he throws in enough dirt to cover about three-fourths of the pipe. He then floods the ditch and after the earth has dried sufficiently he tamps it under the pipe.

irrigator is likely to be sprayed with water when closing an outlet. Furthermore, it often is difficult to remove the caps because of rust. Trouble from this cause may be reduced by frequently coating the threads with graphite grease.

A better type of outlet is shown in Figure 16. It is usually cemented to the inside of the bell of the riser pipe. The valve

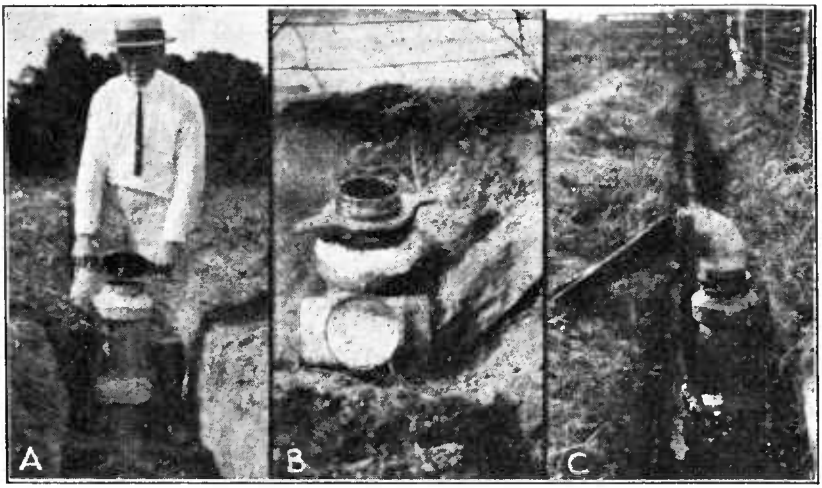

FIGURE 16.—Quick-acting irrigation valve for sewer-pipe system: A, valve with its cover removed, also short riser pipe connecting valve with main; B, valve with part of portable tee hood attached, showing its separable feature; C, valve with portable elbow hood attached. The elbow or tee may be pointed in any direction

is closed by placing the cover over the opening and giving it a short, quick turn to the right, and is opened by reversing the process. This type of outlet may be used successfully where it is not necessary to regulate the quantity of water leaving the valve. Where regulation is desired a 4-inch or even a 3-inch steel pipe nipple with gate valve may be used (fig. 13), or an alfalfa or orchard valve (fig. 17) such as is used in the concrete-pipe irrigation systems of the West.

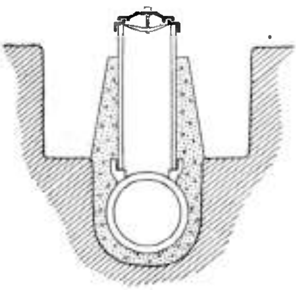

FIGURE 17.—Alfalfa or orchard valve outlet from sewer-pipe distribution line

Usually, water is allowed simply to spill from the top of the valve into a ditch from which it is taken out through one or more openings in the ditch bank for broad flooding or through many openings for furrow irrigation. In the latter case, the flow in each furrow is regulated with a shovel or by means of short lengths of iron or lath pipe, as previously mentioned.

Where it is desired to use portable pipe (p. 30) a special portable hood is necessary. (Fig. 16.) Hoods arranged to fit the commercial irrigation valves may be purchased from the valve makers, but if outlets made of pipe fittings are used, each irrigator must devise his own. Only one portable hood is needed for a number of valves.

Either one of the hoods made to fit the valve shown in Figure 16, clamps to the valve casting in the same way as the cover. The sheet-iron connecting piece, with its short canvas hose attached, may be turned in any direction.

Generally it is unwise to use sewer pipe under pressure where the ground freezes to a depth of more than a foot. In any case the top of the pipe should be at least a foot below freezing, as considerable changes in temperature seem to cause trouble in sewer-pipe lines even though the pipe is buried below danger from heaving ground. The uprights leading from the main to the surface must be protected; otherwise heaving of the ground due to frost often will break the connection between the valves and the underground main. The tapered concrete block recommended on page 23 is designed in part to overcome this trouble. There should never be any projecting shoulder for heaving ground to raise; any valve with projections should be placed several inches above the ground.

Sewer pipe when used in the Northern States should be laid at such slopes as will permit it to be drained easily. Drain cocks may be placed in the pipe at low places, these being made by cutting a hole in the pipe with a cold chisel at each low point and cementing in a short piece of 1-inch iron pipe connected to a cut-off valve, or closed with a cap. The drain is set near the bottom of the pipe.

It is not safe to pump directly into a sewer-pipe system unless some sort of pressure-relief device is provided. The surest device for this purpose is an open standpipe (fig. 18) with its top at an elevation a few feet above that of the highest ground to be irrigated. Then if the pump is operated with all the valves closed the standpipe will permit the water to overflow, thus preventing the pressure from bursting the pipe. Such a standpipe should be placed between the pump and the sewer-pipe line; it should be placed on the discharge side of the check valve if one is used. Similar standpipes should be placed near the closed ends of long laterals as well as of all laterals of even moderate length if the far ends are at low elevations. A cheap and convenient standpipe may be made by cementing together a few joints of pipe, as shown in Figure 18. Sometimes large standpipes (18 inches or more) are constructed in the field to act as diversion boxes or junctions where branches are taken off. Usually they are fitted with slide gates and serve as a means to shift water from one lateral to another. Such a diversion box is shown in Figure 19.

Often where gullies must be crossed, provision must be made to get water to higher land without putting too much pressure on the sewer pipe at the low point. This may be done by bringing the pipe above ground and supporting it on a trestle where it crosses the low ground. Where a trestle would be inconvenient it may be desirable to use underground pipe of other material capable of standing higher pressure.

Sometimes it is possible to use a combination system of sewer pipe and open ditch, the pipe being used to carry water over rough or gravelly ground, or across small ridges or hollows. The ditch then may be used to carry the water over parts of the farm where the slopes are suitable and where open ditches would not be wasteful of water nor interfere with teaming. Water can be taken into the furrows either from the ditch or from the pipe. The combination often

will mean a considerable saving in the cost of the distributing system. The combination system, however, calls for the use of somewhat larger pipe than would be the case in a pipe system, as only gravity pressure is available. The use of open ditches is in no case advisable if the soil is so sandy or porous that much waste by seepage would occur.

CAST-IRON PIPE SYSTEMS

The thinner types of cast-iron pipe are well suited for use in most eastern irrigation systems, either for the complete piping layout or for only the high-pressure parts. Cast-iron water pipe class A or

FIGURE 18.—Relief standpipe. Where not more than three lengths of pipe are used the supporting tower is not needed

class B, standard cast-iron gas pipe, or extra-heavy cast-iron soil pipe, all are suitable for this use. For irrigation service it is proper to use the soil pipe for heads up to 100 feet, the gas pipe and class A water pipe up to 150 feet, and class B water pipe up to 250 feet. Soil pipe is furnished in 5-foot lengths and the others in 12 and 16 foot lengths. In any case, bell-and-spigot pipe, and not flanged pipe, should be used, and because of the saving in labor required for jointing the longer lengths are preferable. Instructions for making joints are given in Farmers' Bulletin 1426, Farm Plumbing. Cast-iron pipe should be covered at least 15 inches over its top, and where it passes under farm roads it should be protected from injury by the wheels of heavily loaded wagons in case ruts form.

Outlets for cast-iron pipe lines should be spaced 30 to 100 feet apart as for sewer-pipe systems. An outlet is conveniently made by inserting a short piece of standard wrought-steel pipe into the side bell of a cast-iron tee, and using a standard valve to control the discharge. A 3-inch valve ordinarily is large enough for an outlet. A bushing, in addition to a nipple and valve, may be necessary if cast-iron tees with 3-inch side outlets are not obtainable. The same joint material as is used for the other joints in the system may be employed to attach the wrought-steel pipe to the cast-iron tee. Usually, no pressure-relief arrangements are necessary if water is supplied by gravity, by city main, or by a centrifugal pump; but if supplied by a plunger pump a suitable relief valve should be provided at some convenient point, or an open standpipe erected at the highest place in the pipe line. If there is danger from freezing, the pipes should be so laid that they may be drained at all low points. At each of these places a hole should be drilled in the lower part of the pipe and tapped for a 1-inch standard pipe fitting, and a plug or stopcock inserted.

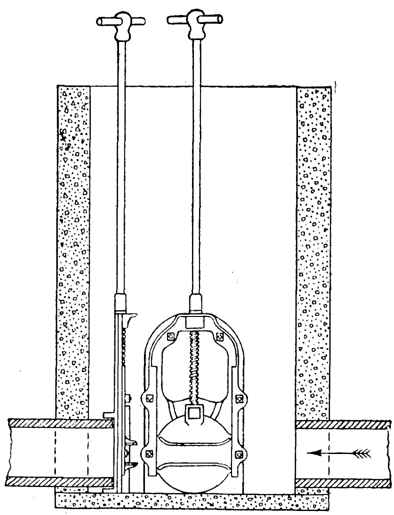

FIGURE 19.—Combination standpipe and diversion box, built of concrete

OTHER PIPE SYSTEMS

Cast-iron pipe is the most durable of all metal pipes used in irrigation. Galvanized and black wrought-steel pipe generally is the most quickly obtained and installed and where these factors are more important than the extra cost it is good pipe for irrigation purposes. Galvanized lightweight riveted-steel pipe is satisfactory where it can be supported above the ground, as along fence lines. Wood pipe has many good points for irrigation service, but the problems of protecting it from early decay are serious. High-grade concrete pipe—both plain and reinforced—is suitable for irrigation work and is widely used in the West. In the East, the cost of such pipe has, up to the present time, prevented its extensive use in irrigation, but this objection is now being overcome, and some concrete-pipe systems recently have been installed. Bell-end pipe, installed in the same manner as suggested for clay sewer pipe, is recommended.

APPLYING WATER TO CROPS

A certain degree of skill is necessary to irrigate properly by any method. This can be attained only by practice. Therefore the amount of water to apply and the exact procedure in applying it can not be definitely set down in words. While it is likely that the observant eastern farmer with his frequent opportunities to watch the effect on his crops of the varying moisture conditions is not likely

to go far astray in judging when the proper moisture condition has been attained by his irrigation practice, yet certain principles may be of aid to the beginner.

FURROW IRRIGATION

In furrow irrigation the water is generally diverted from the distribution system into head ditches and from them into the field furrows. (Figs. 20 and 21.) A sandy loam underlain by a tight subsoil probably is the easiest and most satisfactory soil to irrigate by this method, if the slope of the land is favorable. Such a soil, with a slope of from 4 inches to 1 foot per 100 feet, will allow water to reach the plant roots and still run a considerable distance down open furrows.

FIGURE 20.—Furrow irrigation. Water is being delivered from a specially designed outlet valve which is connected to underground sewer-pipe system

The amount of moisture in the ground before an irrigation is begun and the kind of crop grown will largely determine the quantity of water to be used in that irrigation. In light, loamy soil the water may be applied by running it for only a short time in each furrow, but a much longer time will be required for a heavy soil. Usually water should be let into each furrow and made to reach the lower end as quickly as possible; the quantity entering each furrow can then be decreased as necessary, although the regulation should be such that a sufficient supply will always reach the end of the furrow. This method may be expected to give the most uniform distribution of the water.

The irrigator can determine whether the water has run long enough by digging down to the roots of the plants, at several points along a row, and noting the depth the water has reached. If it has gone below the root zone, water is being wasted. It is best not to

wet the surface of the ground in the row of plants, but to allow the water to seep into the soil from furrows or middles between the rows. This will prevent the soil in the rows from later baking and cracking.

Very sandy soil usually requires that a large quantity of water be applied to each furrow, as it is necessary to get the water to the lower end of the furrow quickly to prevent loss by deep seepage. The slopes of the ground will affect the rate of applying water. If it is put on too rapidly the soils will wash badly on steep slopes, and if the ground is flat the water will not reach the ends of the furrows but will form puddles at the upper ends. Washing may be overcome either by letting smaller quantities of water into the furrows, or by decreasing their slopes by running them diagonally

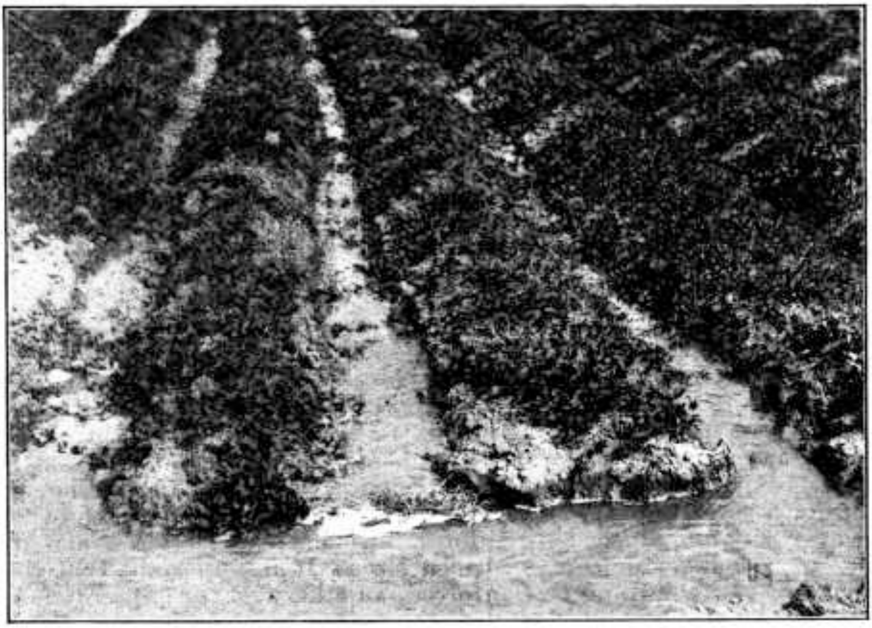

FIGURE 21.—Furrow irrigation from open-ditch system

across the field. For very flat slopes it often is necessary to use the portable pipe or hose later described.

Heavy clay soils usually require that smaller quantities of water be applied in each furrow; the furrows should be deep and narrow, and the water should be run for a longer time. Such soils call for less water for each irrigation, and they hold the water better than the sandy types. However, the irrigator must watch each furrow very carefully or he will waste water at the lower end. For heavy soils it is highly desirable that the distributing apparatus be such that it may be adjusted closely, so that the water will be divided equally among a large number of furrows.

Unless the plants completely shade the ground cultivation is very necessary after each irrigation and should follow as soon as the condition of the soil will permit.

If the ground is dry at the time of planting, some irrigators plant in furrows which have been wetted down previously by irrigation; others plant between furrows that are close together, and then allow the water to run long enough to soak the seed bed thoroughly.

Often, furrows 400 to 600 feet long (and sometimes even longer) may be used satisfactorily, but generally shorter lengths are advisable. If the furrows are found to be too long it may be necessary to run another pipe line or ditch parallel with the head line, about halfway down the furrows. In small market gardens the furrows often are not over 100 feet long. If the furrows are shorter the water may be controlled more satisfactorily, and less waste will occur.

Where a combination of spray and furrow systems seems necessary, the former should be used to irrigate seed beds or closely planted garden truck, and the furrow system for such crops as potatoes, sweet corn, Lima beans, rhubarb, and berries, as well as celery after it has been set out from the seed beds. It may be practicable to do without the spray system if the seeds are planted in beds 3 to 10 feet wide which may be irrigated from furrows cut between them. The water should then be kept in the furrows long enough to allow it to seep across the beds. This method may be followed on land that is nearly level, provided that the surface soil is light and that it is underlain by heavier soil. Furrow irrigation of seed beds on heavy clay soils is very difficult and requires considerable patience and experience.

USE OF PORTABLE PIPE AND HOSE

If the soil to be irrigated is very sandy, or the land is too flat to permit the water to run down the rows or furrows, or the quantity of water is limited, the use of portable pipe may be desirable. Portable pipe usually is made in 10-foot sections of lightweight sheet iron, one end of each section being slightly tapered so that it may be pushed into the untapered end of the following section to make a fairly tight joint. The pipe should be made of 24 to 26 gauge galvanized sheet iron for 6-inch and smaller sizes, and of 22 to 24 gauge for 8 and 10 inch sizes. It is important that the ends of portable pipe be reinforced, as otherwise the pipe often is ruined by the breaking of the seams when the sections are being connected or disconnected. This reinforcing should be done with iron of not less than 18 to 20 gauge. Several firms make this pipe, and local tinners usually can make it or order it for the irrigator. Some prefer the less durable but more easily obtained conductor pipe, which generally is used in the 3 or 4 inch size.

Homemade canvas hose about 10 feet long is used to connect the outlet hood with the nearest section of portable pipe. (Figs. 16, C and 22.) One end of this hose is connected to the hood discharge, generally by tightly wound wire, and the other end is simply thrust into the nearest end of the portable pipe. Such a connection is quickly made and is very flexible.

In use, the portable pipe may be built up section by section as irrigation proceeds, or the entire length may be built up first and the sections disconnected as necessary. When the limit of one setting of the portable pipe line is reached, the operation is repeated with a new setting of the pipe. Portable pipe is very convenient for irrigating hay crops and is used extensively in the West for irri-

gating alfalfa where the soil conditions are not favorable for wide flooding. (Fig. 23.)

On account of leakage it is very difficult to force water even a few inches uphill through ordinary portable pipe. Some eastern irri-

FIGURE 22.—Irrigating with 6-inch portable pipe, showing the first length of portable pipe and the homemade canvas hose that connects it with the outlet hood

gators have reduced leaks at the joints by laying the pipe at a uniform slope, using portable wooden trestles where necessary. (Fig. 24.) One way of reducing leakage is to have two or three lugs

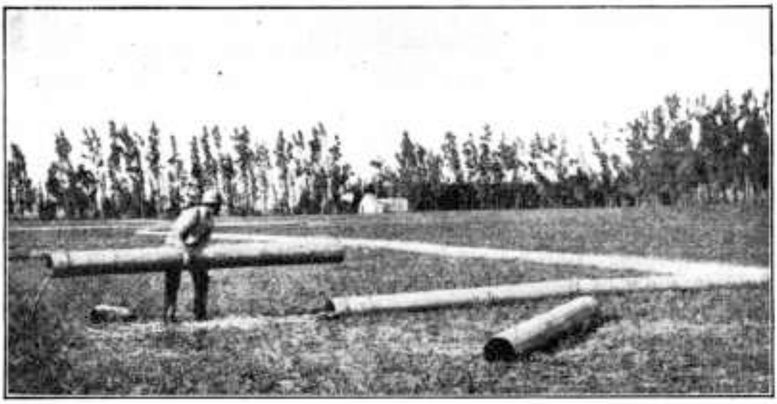

FIGURE 23.—Use of portable galvanized-iron pipe in alfalfa irrigation

firmly attached near each end of each section of portable pipe and to fasten the sections of pipe together with a turn of hay wire when applying water to higher ground. Only a small rise in ground sur-

face can be overcome by this method. Another plan is to have the tapered and reinforced ends of the sections extra long and heavy and to use lugs containing bolt holes. Bolts can then be put through the lugs and the pipe drawn up with nuts, usually making a fairly tight joint. Western irrigators have used tarred cloth or burlap between the taper and the ring. Where water must be forced up a considerable slope it sometimes is necessary to obtain extra-light spiral-riveted pipe and to use a bolted joint. The time necessary to make connections renders this method too slow, however, if the pipe needs to be carried from place to place very often.

Hose is sometimes used instead of portable pipe to convey water. However, it is not as durable as pipe and is soon worn out by being dragged over the field. It is subject also to attack by insects, rats, and mice, when stored for the winter, and is hard to handle unless the diameter is small and the lengths are short. Hose will drag down tender plants unless it is handled very carefully. If used at all, it should be dried out after each irrigation and stored in a dry place.

FIGURE 24.—Portable galvanized-iron pipe line supported by wooden trestles

For small quantities of water ordinary garden hose can be used. Condemned fire hose, up to 2½ inches in diameter, sometimes can be bought cheaply. The connections on fire hose are of the quick-turning variety. Fifty-foot lengths usually are best. Cheap 2 to 8 inch hose may be homemade from strips of heavy duck or canvas by sewing a double seam with very heavy thread. A local harness maker or cobbler who has suitable machines for such work should be able to make a strong hose of this sort. The canvas hose may be joined by simply shoving the discharge end of each 50-foot section about 3 feet into the next length. The pressure of the water tightens the connection. In irrigating, the hose sections may be separated by a simple jerk.

FLOODING AND CHECK METHODS

The flooding method consists merely in permitting the water to flow more or less uncontrolled over the land, generally from open-

ings cut in the banks of open ditches. Though apparently simple, this is generally a laborious process, owing to the amount of shovel work required and the necessity of wading in the saturated ground. This method is illustrated in Figure 25.

The check method of irrigation, which in the humid section reaches its widest use in the irrigation of rice, consists in flooding "checks" formed by small dykes or levees located on contours (the lines joining points of equal elevation) at about 3 to 6 inch differences of elevation and suitably connected by cross levees. These checks usually vary in size from about one-half acre to several acres. Directions for laying off and building checks are contained in Farmers' Bulletin 864, Practical Information for Beginners in Irrigation. This method with modifications is also used for the irrigation of cranberries.

FIGURE 25.—Flooding from an open ditch

COST OF IRRIGATION[4]

At present the most important item of expense for irrigation in the Eastern States is the cost of the plant. This may amount to only a few dollars per acre irrigated where a gravity flow is available and water is distributed to the field entirely through open ditches. In a number of such cases, especially in the South, considerable areas have been watered for $10 or less per acre. Those systems required only short gravity ditches leading directly from streams or flowing wells. A more expensive plant is necessary where the water supply must be stored. Systems using flowing wells that yield only 40 to 60 gallons per minute have been used to irrigate 10 to 20 acres, with the assistance of storage reservoirs constructed in clay soil.

Irrigation plants with low pumping lift and open-ditch distribution systems also are comparatively cheap. An open-ditch system

[4] Cost figures given are based upon prices quoted in 1929.

to irrigate a 20-acre field adjacent to a stream should cost, installed, not more than $20 to $25 per acre, if the pump is to be operated by a tractor whose cost is already charged to some other item of farm operation. Areas larger than 20 acres, under the same circumstances, could generally be irrigated at somewhat lower costs per acre. A similar plant for a field of 100 acres should not cost over $17 or $18 per acre.

A complete sewer-pipe distribution system for a 20-acre field with a near-by water supply might cost as much as $80 or $90 per acre for tractor operation, and if equipped with a farm engine $10 or $12 more per acre if the lift were less than 30 feet, or $20 to $25 more per acre if the lift were between 30 and 60 feet. Under the most favorable conditions, where the irrigation water could be run long distances in the furrows, such a plant might be installed for as little as $45 per acre for tractor operation. On the other hand if the pump lift were, say, 70 feet and the field were 1,000 feet from the water supply, another $60 to $90 per acre might easily be added to the cost of the outfit although the cost of the field-distributing system should be about the same as for the lower lift. As in the case of the open-ditch system it should be possible to install a system for more than 20 acres at correspondingly lower costs.

Where a well must be bored and a deep-well pump installed, the simplest irrigation system probably would cost not less than $100 per acre, even for tractor operation.

Table 3 shows costs of pipe of various kinds adapted to use in surface irrigation which, together with the pump-cost figures shown in Table 1, and the engine costs given on page 14, should enable one to estimate the approximate cost of a complete irrigation system. The prices shown in Table 3 are subject to wide changes, and one who is considering irrigation should inform himself as to current prices.

TABLE 3.—*Approximate cost*[1] *per foot of pipe adapted to surface irrigation systems*

Diameter	Kind of pipe				
	Sewer pipe	Cast iron, class A	Cast iron, extra heavy soil	Wrought steel, black	Wrought steel, galvanized
Inches	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
¾	----------	----------	----------	0.06	0.08
1	----------	----------	----------	.09	.11
1¼	----------	----------	----------	.12	.14
1½	----------	----------	----------	.14	.17
2	----------	----------	0.20	.19	.23
2½	----------	----------	----------	.28	.36
3	----------	0.36	.31	.38	.48
4	0.11	.50	.42	.55	.68
5	----------	.63	.54	.74	.92
6	.13	.77	.63	.96	1.19
7	----------	----------	----------	1.19	----------
8	.21	1.05	----------	1.25	----------
10	.28	1.40	----------	1.60	----------
12	.37	1.75	----------	2.25	----------
15	.54	----------	----------	----------	----------

[1] Based on prices quoted in 1929

Suitable outlet valves can be obtained at prices ranging from \$1.50 to \$6 each. Trenching and laying should be done for from 8 to 12 cents per running foot for the sizes ordinarily used in the East, the higher cost applying to clay soil where trenching is expensive.

The operating cost of most furrow-irrigation plants in the East is not great, as crops ordinarily need to be irrigated only a few times each season to carry them through periods of drought. At 25 cents per gallon for gasoline and 25 cents per quart for lubricating oil the annual operating costs should not exceed \$5 per acre per year for a 50-foot lift, or \$10 per acre per year for a 100-foot lift in the case of a 20-acre plant, and for larger outfits they should be less. This assumes that the engine attendant does other farm work primarily and that no labor charge is made against ordinary operation. However, the interest on first cost and the depreciation of the plant must be considered carefully as these items often are the deciding factors in determining whether a pumping outfit will pay. Yearly interest and depreciation would range from 10 to 20 per cent; perhaps an average of 15 per cent would hold for most surface-irrigation plants. Field-labor charges are important and must not be neglected. One man usually is able to irrigate from 1½ to 3 acres per day by the furrow method, and somewhat less by portable pipe.

Example 1.—If an outfit will cost \$75 an acre to install complete with engine or motor, and it is decided to allow 20 per cent for interest, taxes, and depreciation, it is then necessary to figure $\$75 \times 0.20 = \$15$ annually for these items with, say, \$10 per acre per year for fuel and \$5 per acre per year for repairs and incidentals. In addition to this, there will be an expense of perhaps \$5 per acre per year for field labor (assuming that labor will cost \$4 per day, that a man will irrigate 2 acres per day, and that two and one-half irrigations per season will be the average need). The average annual cost per acre chargeable to irrigation, then may be expected to be $\$15+\$10+\$5+\$5=\$35$. This means that before any profit can come from the irrigation investment the crops irrigated must yield an average of \$35 per acre more than those raised on the same land without irrigation. A yield of less than this amount during some years would be permissible if much more is received in others, provided the proper average is maintained.

Example 2.—Consider the question of installing surface irrigation for potatoes in southern New Jersey. Accurate records of irrigation of that crop in the above-mentioned locality for 7 intermittent years out of 14 successive years, showed an increase due to irrigation of 40 bushels per acre per year. Assuming that no increase would have been obtained had irrigation been practiced during the other seven years, these results would indicate that a year-in, year-out increase of 20 bushels per acre could be expected to result from irrigation. These at \$1 per bushel (in the three years when the selling price was reported it was about \$1.50 per bushel) would indicate that an increased return of \$20 per acre per year could properly be credited to irrigation. Irrigation often justifies the application of larger amounts of fertilizer than can be economically used on unirrigated lands. Such increased applications may result in still further

returns, but let it be assumed that only $20 per acre per year can be expected.

Under what conditions, then, can an irrigation system be installed and operated for a total cost of less than this $20 per acre per year? Only under very favorable conditions could irrigation be provided on a 20-acre tract for less than $20 per acre per year (including interest, taxes, depreciation, and upkeep and operation costs) if it were necessary to use pumped water. In southern New Jersey it should be possible to provide 40 acres of open-ditch irrigation on tracts with favorable slopes, where the total lift is not over 20 feet, for about $16 per acre per year (including overhead and operation) where water is taken from an open pond or lake and the pump is driven by tractor. Under similar conditions it should be possible to provide irrigation for a 100-acre tract for somewhat less than $13 per acre per year. On tracts of more than 100 acres a further reduction in annual cost would generally be possible with other conditions equally favorable. Increasing the lift from 20 to 30 feet probably would not increase the total annual cost more than $1 per acre per year, provided the change did not put the power requirement above that of the power available in a tractor already at hand; and another 10-foot increase in lift might be made at the same additional cost, subject to the same provision. The above figures permit the use of no pipe other than suction pipe and a short discharge pipe. They therefore indicate that any water supply to be useful for potato irrigation must be near the field on which it is to be used and that irrigation under a lift of 20 feet is more profitable than that under a lift of 40 feet, although the cost of raising water to the latter height is not excessive for a large tract. A crop that would by irrigation be increased in value more than the $20 above allowed, would, of course, justify a greater lift or more pipe; on the other hand a crop on the same tract with a less valuable increase would be profitable only under a smaller lift.

While the foregoing figures apply in particular to southern New Jersey, they are applicable to a large part of the eastern area where irrigation is practiced.

Records for seven consecutive years in southern Wisconsin indicated an average increase of onions, due to irrigation, of 131 bushels per acre. Records of tomato irrigation in the same locality showed an increase in yield of more than 4 tons per acre per year for the same period. On the other hand, four consecutive year's records in New Jersey showed an average increase of only one-half ton of tomatoes per acre per year. It should be noted with reference to the figures given that they are averages during a period that included wet as well as dry years. The increased quantity of tomatoes in New Jersey, for instance, was 2 tons per acre, and was all in one dry year; but as the record covers four years the average was one-half ton per acre per year. These figures indicate that in southern Wisconsin, at least, when the increased crop value is considered, an expensive system for the irrigation of onions may well be justified. For the irrigation of tomatoes an expensive outfit is also warranted if the crop can be placed on the market for direct consumption; but the increased profits to be expected from tomatoes for the cannery indicate that for them only moderate-priced equipment can be expected to be profitable.

The crop results set forth illustrate the well-known fact that some crops respond well to irrigation. But it must not be overlooked that both the increase in yield and the increase in value per acre resulting from irrigation vary considerably with the different crops and with the locality in which they are grown. Satisfactory figures of average irrigation increases of many crops are difficult to obtain. In general, the farmer who considers taking up the practice must judge for himself how valuable irrigation would be to him, and he must do this with little definite data to guide him. Careful investigation, however, would doubtless show some eastern farmers a chance to benefit by the use of surface irrigation.

INFORMATION NEEDED IN THE DESIGN OF A PLANT

The United States Department of Agriculture receives many letters asking for information regarding irrigation in the Eastern States. Before helpful advice can be given it is necessary to have the following information:

Acreage to be irrigated.

Kind of soil.

Source of water supply; estimated quantity available. (If a well, the size and type of well, distance to water, and probable draw down when pumped.)

Distance from water supply to land to be irrigated.

Difference in elevation between water supply and land to be irrigated.

Crops to be irrigated.

The general slopes of the land to be watered.

A sketch showing slopes of the land to be irrigated, location of the water supply, etc. It will be sufficient if this map indicates directions of slope by arrows and amount of slope in inches per 100 feet. An accurate topographic map is, however, very helpful and may be the means of a considerable saving.

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August 20, 1930

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